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**Patentanmeldung Nr. | Patent application No. | Demande de brevet n°**

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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R C van Dijk

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(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
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Scrolling backlight addressing

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Scrolling backlight addressing

The present invention relates to a backlight comprising a light guide wherein light from a light source is constrained by total internal reflection (TIR). The invention also relates to a method for addressing a display device having a light guide wherein light from a light source is constrained by total internal reflection (TIR).

Such displays are normally addressed with passive matrix addressing, and the dynamic foil display as described in e.g. WO00/38163 is an example of such a display.

In such displays, grey scales can be generated by using pulse width modulation. According to WO00/38163, addressing is performed in the way illustrated in Fig. 1a. The rows are addressed sequentially during a first scan, to allow switching all pixels ON, and then a second scan is performed during which all pixels are switched to the OFF state. A frame period (typically 20 ms) is divided into several pairs of such ON- and OFF-scans, each such pair being referred to as a sub-field. Grey scales can be accomplished by pulse width modulation, switching a pixel ON during appropriate sub-fields. For this purpose, sub-fields are weighted, for example in a binary fashion (binary weighted sub-fields, BWS), by having different duration, as shown in Fig. 1a.

Another way to address such a display is by separate addressing periods and display periods, as is shown in Fig. 1b. The light source is only activated during the display periods, which thus define the sub-fields. Again, the duration of different sub-fields are different.

An important parameter of an addressing scheme is the number of "time slots" which are needed for a full scheme within a frame period, since that determines the available row selection (addressing) time. Roughly stated, the larger the addressing time, the easier it is to address correctly. The scheme illustrated in Fig. 1a and 1b are simple, but rather inefficient addressing scheme, as there is an idle period between each scan including a number of time slots equal to the number of lines in the display. Moreover, this addressing scheme requires a large number of slots, resulting in a very small slot time, which makes the display difficult to address.

These addressing schemes can be improved by using a modulated light source, so that the intensity of the backlight defines the sub-field length instead of the duration. Such an addressing scheme is described in e.g. US 6,317,112, and is illustrated in Figs. 2a and 2b. However, the light modulation itself restricts further improvements of efficiency, as it requires a separation of the sub-fields in time (time separated subfields, TSS). It is apparent from Fig. 2a and 2b that these schemes result in significant dead-time. In Fig. 2a, although the backlight is always activated, there is an idle period on each row between an OFF-addressing and the next ON-addressing. In Fig. 2b, the whole backlight is switched OFF while the rows are being addressed, causing dead-time.

Instead of using light modulation, the addressing scheme in Fig. 1a can be improved by interleaving the ON- and OFF-scans, as is illustrated in Fig. 3. While improving the efficiency, such a scheme makes it impossible to use light modulation according to US 6,317,112, as the sub-fields can no longer be separated in time.

It is an object of the present invention to provide an improved addressing of bi-stable optical displays.

In particular, it is an object to provide an improved method for modulating the light source.

These and further objects are achieved by a device and a method of the kind mentioned by way of introduction, wherein the light source is arranged to simultaneously and in a scrolling fashion couple light of different modulation into different sections of said light guide, each section comprising a number of lines of the display.

The display and method according to the invention can advantageously be implemented in time separated subfield schemes, such as the schemes in Figs. 2a and 2b, as well as in interleaved schemes, such as the one in Fig. 3. A modulated backlight illuminating different sections of the light guide in a scrolling manner can increase the efficiency of these subfield schemes significantly, thereby increasing the slot time making the display easier to operate.

The modulation can be intensity modulation, in which case the invention provides an improved way to generate gray scales.

Alternatively, or in combination, the modulation can be color modulation, thus providing an improved color sequential addressing. With color sequential addressing the color filter of the display can be omitted, and the number of column drivers reduces with a

factor of three (since no subdivision into 3 colored subpixels is needed). This leads to a significant cost reduction.

Further, the 'fill factor' i.e. the effective pixel area is increased by a factor of three, as there is only needed one pixel instead of three differently colored sub-pixels. In a foil display, the density of spacers is thus reduced and the contact area between foil and active plate is increased. This gives an additional brightness increase.

Also, in the case of a foil display, as the need for a color filter is eliminated, the light can now be extracted directly from the light guide, instead of passing through the passive plate, i.e. the light guide can be arranged towards the viewer (strictly speaking it will become a "frontlight" instead of a "backlight". The flexible element (foil) can in this case be coated with a mirror to reflect all light towards the light guide. This enhances the brightness with a factor two.

The light source preferably comprises a plurality of lighting units and a control unit for controlling the modulation of each lighting unit. This enables altering the illumination of each section of the light guide, to thereby achieve the scrolling of light across the display.

In the case of color modulation, each lighting unit may comprise a plurality of lighting elements arranged to provide light of different color, such as red, green and blue. These lighting elements can then be alternatingly activated by the control unit.

In the case of intensity modulation, the lighting units can be arranged to provide light with varying intensity. The intensity can then be controlled by the control unit.

According to one embodiment, the light guide comprises a plurality of light guide portions, and each lighting unit is optically coupled to one of the light guide portions. According to another embodiment, the lighting units are arranged to direct collimated light beams into the side of the light guide, in parallel with the lines (rows) of the display, to thereby illuminate only one section of the light guide.

The backlight according to the invention can advantageously be incorporated in a display device adapted for the use of backlighting.

In particular, the backlight can be used in a foil display device, further comprising a flexible element, and two sets of parallel electrodes arranged to bring selected portions of the flexible element into contact with the light guide in order to extract light from the light guide.

According to a second aspect of the invention, the above objects are achieved by a method for addressing a display device of the kind mentioned by way of introduction,

further comprising simultaneously and in a scrolling fashion coupling light with different modulation from the light source into different sections of the light guide, each section comprising a number of lines of the display.

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing currently preferred embodiments of the invention.

Figs. 1a and 1b illustrate two prior art addressing schemes with time seperated sub-fields (TSS) for a display having bi-stable pixel elements.

Figs. 2a and 2b illustrate two further prior art (non-TSS) addressing schemes, advantageously used in combination with modulation of the light source.

Fig. 3 illustrates yet another prior art addressing scheme.

Fig. 4 is a schematic side view of a dynamic foil display.

Fig. 5 illustrates the switching curves of a pixel element of the display in Fig. 4.

Fig. 6 is a schematic perspective view of a first embodiment of a backlight according to the present invention.

Fig. 7 is a schematic perspective view of a second embodiment of a backlight according to the invention.

Fig. 8 is a schematic side view of a third embodiment of a backlight according to the invention.

Fig. 9a illustrates a variant of the addressing scheme in Fig. 3.

Figs. 9b and 9c illustrate a first embodiment of an addressing scheme according to the invention.

Fig. 10a illustrates a variant of the addressing scheme in Fig. 9a.

Fig. 10b illustrates a second embodiment of an addressing scheme according to the invention.

Figs. 11a and 11b illustrate a third embodiment of an addressing scheme according to the invention.

In the following, the invention will be described in relation to a dynamic foil display, described in e.g. WO00/38163. Such a display is illustrated in Fig. 4, and comprises

a light guide 5 in the form of an edge lit glass plate and a non-lit passive plate 7, with a scattering foil 6 clamped in between. Light from a light source 4 is coupled into the light guide 5. On both plates there are respective sets of parallel electrodes 8, 9 which are arranged perpendicularly with respect to each other. The electrodes 9 on the light guide are referred to as column electrodes, while the electrodes 8 in the back plate are row electrodes. The voltages applied to the electrodes are controlled by a row driver and a column driver, respectively. Pixels are defined by the intersections of rows and columns. By applying suitable voltages to a row and a column electrode, an area of the foil 6 can be brought into contact with the light guide 5, to thereby disturb the total internal reflection and extract light from the light guide 5. Light is normally coupled out through the passive plate 7.

The switching curves of a pixel element of the display in WO00/38163 is shown in Fig. 5, where the x- and y-axis represent the row and column voltages respectively. The bi-stable region 1, between the ON-curve 2 and the OFF-curve 3, creates a memory effect in the pixel element. For a suitable row voltage level ($V_{row,unsel}$), the state of the pixel cannot be switched (neither ON nor OFF) by changing the column voltage level between $V_{col,selON}$ and $V_{col,selOFF}$, but maintains its present state. This memory effect makes it possible to use a passive matrix addressing method to drive the display.

As previously mentioned, examples of conventional addressing schemes are illustrated in Figs. 1-3. In these Figs. (and in the following Figs. 9-11), checked boxes 11 indicate time slots in which the row is provided with voltage $V_{row,selON}$, so that pixels in the row can be activated (turned ON) by providing the desired columns with voltage $V_{col,selON}$, thus placing the pixel in position P4 in Fig. 1. During the following fields 12 the rows are provided with voltage $V_{row,unsel}$, so that pixels will stay on if activated. Black boxes 13 indicate time slots in which the row is provided with voltage $V_{row,selOFF}$, so that pixels may be turned OFF (and always are turned OFF), by providing the desired columns with voltage $V_{col,selOFF}$, thus placing the pixel in position P5 in Fig. 1. The fields 14 indicate time slots during which the rows are again provided with voltage $V_{row,unsel}$, so that pixels will stay OFF. During the periods 12 and 14 the pixels are always in the bi-stable region 1 shown in Fig. 1. In the periods 14, the pixels are further always in the OFF state (position P6 in Fig. 1), while in the periods 12, they may be in different states (ON or OFF) (positions P6 or P7 in Fig. 1), depending on the switching performed in the preceding checked box 11.

The addressing schemes in Figs. 1a, 1b and 3 are adapted to have the light source 4 arranged to provide the light guide 5 with constant light. Efficient generation of gray scales is accomplished by letting the sub-fields 10 have different duration.

The addressing scheme in Fig. 2, on the other hand, is adapted to have a "flashing" light source 4, synchronized with sub-fields 15 of the same length, and adapted to generate differently modulated light. In Fig. 2a, these sub-fields 15 are defined in the same way as in Fig. 1a, using row selective ON and OFF addressing. The backlight is activated from the start of the ON-scan until the end of the corresponding OFF-scan. In Fig. 2b, the backlight is only active during the periods 15, which here are defined by the period occurring after the ON-scan of checked boxes 11 is completed for all rows, and before the whole display is erased at once 16, e.g. by connecting all columns to a voltage close to the foil voltage, above the OFF-curve 3 in Fig. 5.

According to the invention, the light source 4 comprises a plurality of lighting units 20 (see Figs. 6-8), arranged to sequentially illuminate different sections of the light guide 5 with light of different modulation. For example, a lighting unit can comprise three colored LEDs 24 (see Fig. 8) or just one lighting element with adjustable intensity.

In a first embodiment of a backlight according to the invention, shown in Fig. 6, the lighting units 20 are arranged along the side of the light guide 5 to each provide a collimated beam 21 which is aligned with the rows of the display. The light units 20 are controlled by a control unit 22. The light beams 21 enter from the side of the light guide, and stay essentially parallel to the lines (rows) of the display. The optical separation between two adjacent sections 23 of the light guide, defined by the beams 21, will not be perfect, and some cross-talk will appear from one section to the first few rows in the next section. However, such a backlight is relatively easy to manufacture.

In a second embodiment of a backlight according to the invention, shown in Fig. 7, the light guide 5 comprises several joined light guide portions 25, each illuminating L/N rows (where L is the number of lines in the display and N is the number of light guide portions 25). Each light guide portion thus forms a separate section 26 of the light guide 5, each being coupled to a separate lighting unit 20, in principle without permitting light cross-talk between sections. The joining of the light guide portions 25 should be such that the side facing the foil is perfectly optically and mechanically flat, and preferably such that the joins cannot be seen, i.e. the joins coincide with the dead area between the pixels (the row electrodes can be laid exactly on top of them).

A disadvantage of coupling light through the light guide sides, as is done in the backlights in Figs. 6 and 7, is that some non-uniformity can occur along the row. When pixels at the beginning and end of the rows are ON, there is less light available for pixels in the middle of the row than when the former pixels are OFF (in which case the light is

"recycled"). This becomes relatively more serious for increasingly long rows and/or when more pixels in a given row are in the on state.

For this reason, a third and preferred embodiment of the backlight according to the invention comprises a light guide as disclosed in **PHNL020868 (EP application number 02078867.5)**, herewith incorporated by reference. In such a light guide 27, illustrated in Fig. 7 as a cross section across the lines of the display, light 31 is coupled in along the entire length of the rows, through the edges of special incoupling structures 28 (ribs or cubes) that are formed on the back side of the light guide 27, facing the lighting units 20 arranged on the back side. The incoupling structures 28 are adapted to prevent direct-lit light entering the light guide, for example by being coated by a reflective layer 29. In a similar way as the second embodiment of the backlight mentioned above, the light guide 27 in Fig. 8 is separated into a number of sections 26 that are optically separated from each other, by assembling the light guide from a number of smaller plates positioned side-by-side, the edges of each plate being covered with a specular-reflective metal layer 30. The lighting units are divided by placing white-reflective walls between the individual units. As shown in Fig. 8, the compound light guide 27 can optionally be brought into optical contact (e.g. with an optical glue) with a much thinner active plate 5 of the DFD display. This thinner plate has preferrably substantially the same refractive index as the thick light guide to prevent any reflection at their interface.

The described lighting units 20 are further controlled to provide each section 23, 26 of the light guide alternatingly with differently modulated light, in such a way that areas of differently modulated light are scrolled across the display. This scroll can then be aligned with the addressing of rows, to thereby achieve a more compact addressing scheme.

A first embodiment of an addressing scheme according to the invention is based on a scheme illustrated in Fig. 9a, where the scheme in Fig. 3 has been changed to have sub-fields 15 of equal length. Backlight modulation according to the invention is applied as illustrated in Figs. 9b and 9c. The interleaved ON- and OFF-scans from Fig. 9a are indicated schematically by boxes 11 and 13, and the shaded areas 44-46 represent illumination by differently modulated light. Note that conventional light source modulation, for example according to US 6,317,112, is not possible in the scheme in Fig. 9a, as the different sub-fields are not separated in time. According to the invention, different sections (41-42 in Fig. 9b, 41-43 in Fig. 9c) of the display are alternatingly illuminated with light of different modulation, and the sequence is displaced in time for the following sections, so that each sub-field 15 is

illuminated with the same modulation of light, without interfering with the other sub-fields 15.

If the light guide is split into physically separated section 26, as was described above with reference to Figs. 7 and 8, cross-talk between sections 41-42 in Fig. 9b cannot occur. However, care needs to be taken of uniformity across the boundaries.

If the sections 41-42 in Fig. 9b are not optically separated, cross talk may occur between rows being simultaneously illuminated by different colors. For example, when pixels in the last row of section 41 are activated 47, the next section 42 is still being illuminated with a differently modulated light, which may "leak" into the first section, thereby distorting the output from this pixel. In order to avoid such cross-talk, the periods 44-46 should be separated, and this can be accomplished by dividing the display into more sections 41-43, as is shown in Fig. 9c. Here, there are always several rows separating an activated pixel in one section from differently modulated light from another section.

A second embodiment of an addressing scheme according to the invention is based on a scheme illustrated in Fig. 10a, where the order of the rows from the scheme in Fig. 9a has been changed. The first row is taken as the first row in Fig. 3, the second row is taken as the first row in the second third of Fig. 3, and the third row is taken as the first row in the final third of Fig. 3. Then the second rows in the three thirds are taken, and so on. The result is an addressing scheme with three simultaneous scans 51-53 visible, one starting at the top of the screen, one at 1/3 and the last one at 2/3.

Backlight modulation according to the invention can then be aligned with these scans, as shown in Fig. 10b, in principle realized in the same way as the backlight modulation in Figs. 9a and 9b.

A third embodiment of the addressing method according to the invention is illustrated in Figs. 11a and 11b. This scheme is based on a time separated sub-field (TSS) scheme.

By scrolling the backlight together with the addressing scan as proposed above, the illumination can take place as soon as all the rows in a section have been addressed, instead of when all the rows in the entire display have been addressed (as was the case in Fig. 2). As a result, the dead time of the TSS scheme can be reduced thus increasing the light emission time with the same amount.

In Fig. 11a, all rows in a section are erased simultaneously, using row-selective OFF addressing 13 of all the rows in the section simultaneously. Such coinciding OFF addressing has been disclosed in **PHNL 030656 (EP application number 03101637.1)**

An alternative is shown in Fig. 11b, where one row at a time is OFF addressed 13. This avoids simultaneously closing the selection switches for several rows in the IC, which involves a larger dissipation. However, as is clear from Fig. 11b, this scheme requires more addressing slots.

Many modifications of the embodiments described above are possible within the scope of the appended claims. In the illustrated examples the light modulation can be color modulation, intensity modulation, or a combination thereof. Also, the length of the sub-fields 10, which for simplicity are illustrated equal, may be different as in Figs. 1a and 1b.

Further, it should be noted that the terms "row electrodes" and "column electrodes" are used in the description and claims generally to indicate a system of electrodes capable of addressing each pixel independently. This is normally accomplished by two orthogonal sets of parallel electrodes (hence the names), but may equally well be accomplished by two arbitrary sets of electrodes, as long as each pixel is connected to one electrode in each set.

CLAIMS:

1. A backlight comprising a light guide (5) wherein light from a light source (4) is constrained by total internal reflection, characterized in that said light source (4) is arranged to simultaneously and in a scrolling fashion couple light of different modulation into different sections (23;26) of said light guide, each section comprising a number of lines of the display.

2. A backlight according to claim 1, wherein said modulation comprises at least one of color modulation and intensity modulation.

3. A backlight according to claim 1 or 2, wherein said light source (4) comprises a plurality of lighting units (20) and a control unit (22) for controlling the modulation of each lighting unit.

4. A backlight according to claim 3, wherein each lighting unit (20) comprises a plurality of lighting elements (24) arranged to provide light of different color, such as red, green and blue.

5. A backlight according to claim 3, wherein each lighting unit (20) is arranged to provide light of different intensity.

6. A backlight according to one of claims 3-5, wherein said light guide (27) comprises a plurality of light guide portions (25), and wherein each lighting unit (20) is optically coupled to only one of said light guide portions (25).

7. A backlight according to one of claims 3-5, wherein said lighting units (20) are arranged to direct collimated light beams (21) into the side of the light guide (5), in parallel with the lines of the display, to thereby illuminate only one section (23) of said light guide.

8. A display device comprising a backlight according to any of the preceding claims.

9. A display device according to claim 8, further comprising a flexible element (7), and two sets of parallel electrodes (8, 9) arranged to bring selected portions of the flexible element (7) into contact with the light guide (5) in order to extract light from the light guide.

10. A method for addressing a display device having a light guide (5) wherein light from a light source (4) is constrained by total internal reflection, characterized by simultaneously and in a scrolling fashion coupling light with different modulation from said light source (4) into different sections (23; 26) of said light guide (5), each section comprising a number of lines of the display.

11. A method according to claim 10, wherein said modulation comprises at least one of color modulation and intensity modulation.

ABSTRACT:

A backlight comprising a light guide (5) wherein light from a light source (4) is constrained by total internal reflection, wherein the light source (4) is arranged to simultaneously and in a scrolling fashion couple light of different modulation into different sections (26) of said light guide, each section comprising a number of lines of the display. A modulated backlight illuminating different sections of the light guide in a scrolling manner can increase the efficiency of conventional subfield schemes significantly, thereby increasing the slot time making the display easier to operate.

Fig. 7

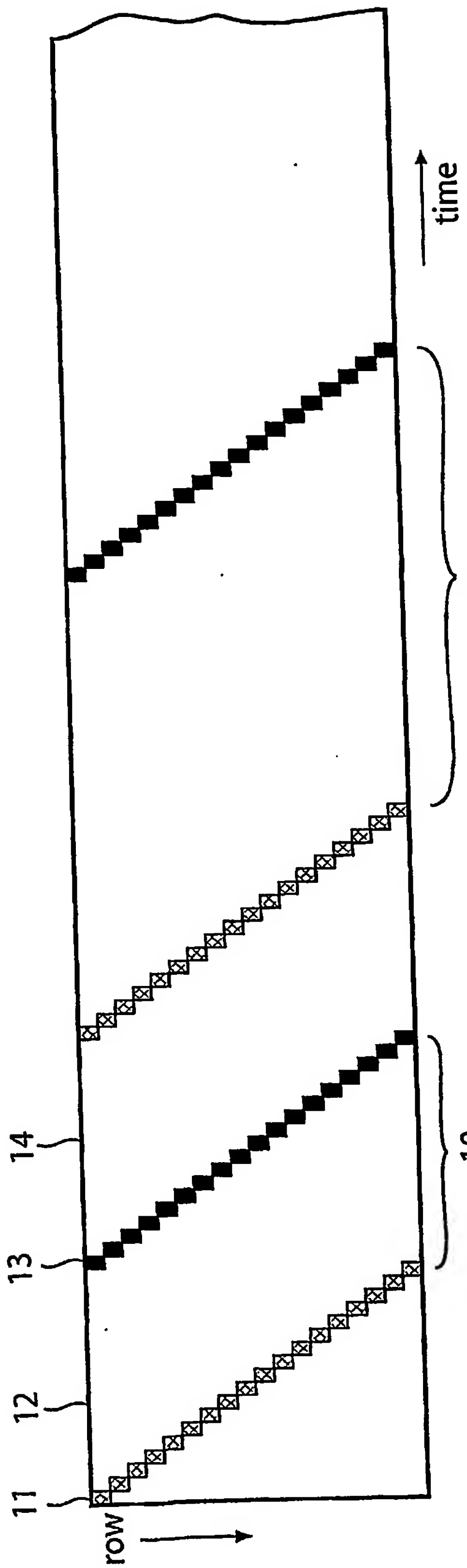


Fig. 1a

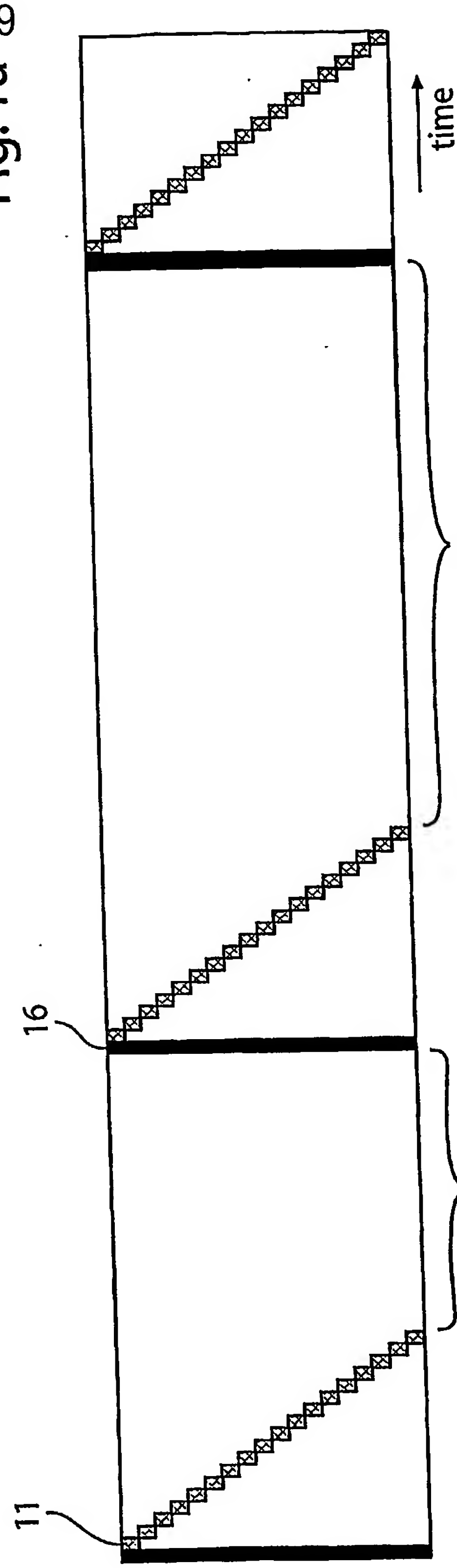


Fig. 1b

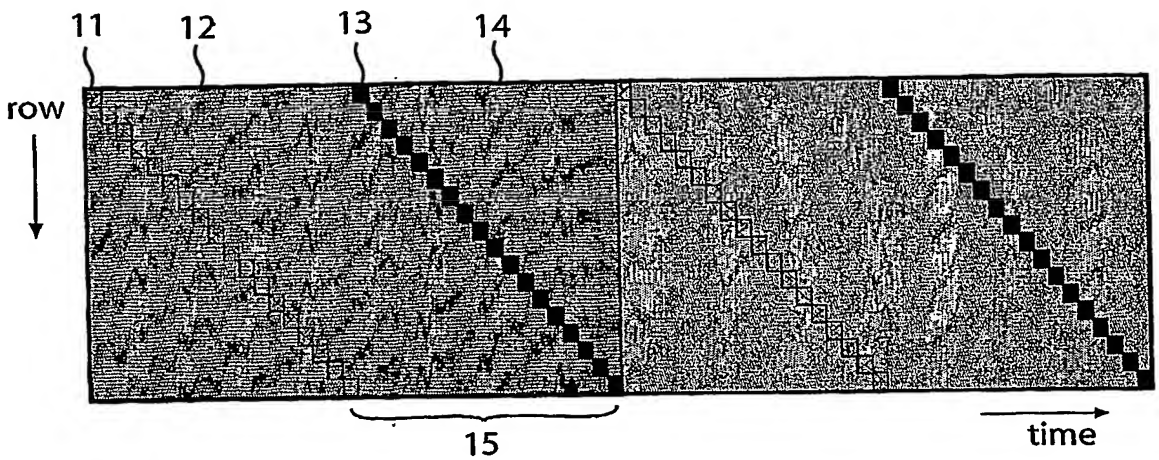


Fig. 2a

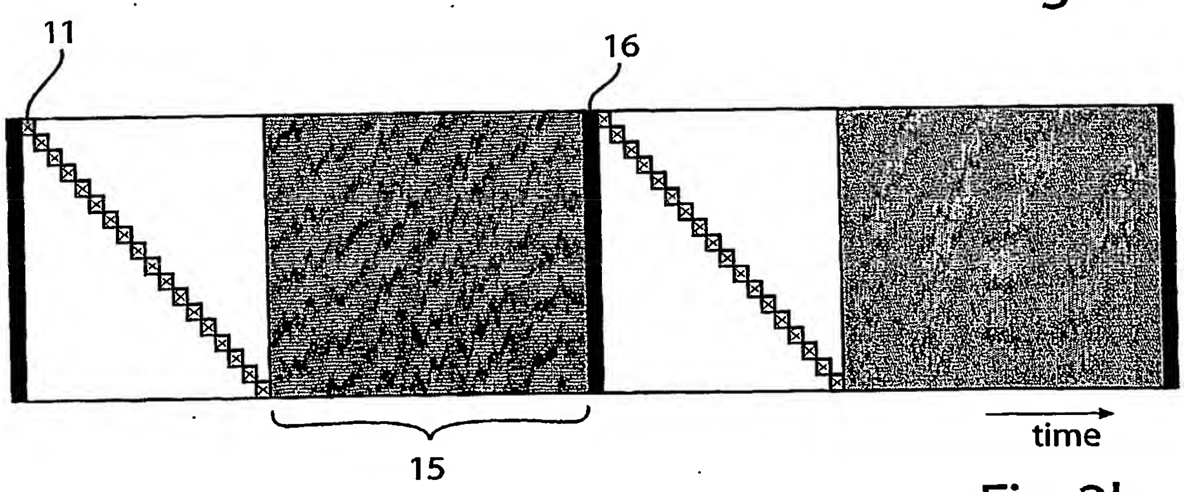


Fig. 2b

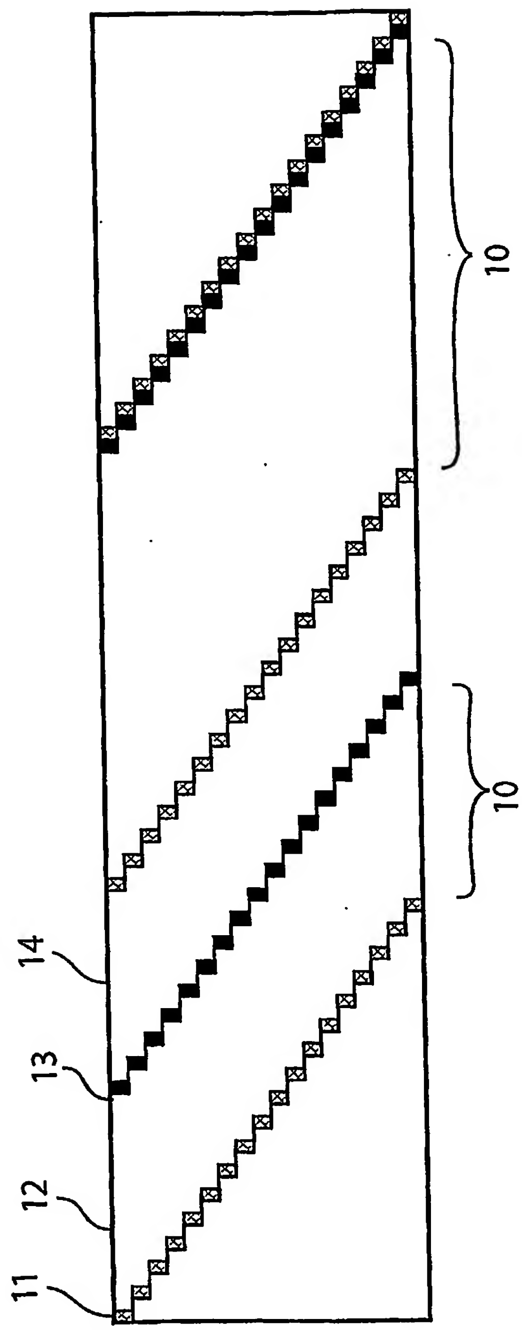


Fig.3

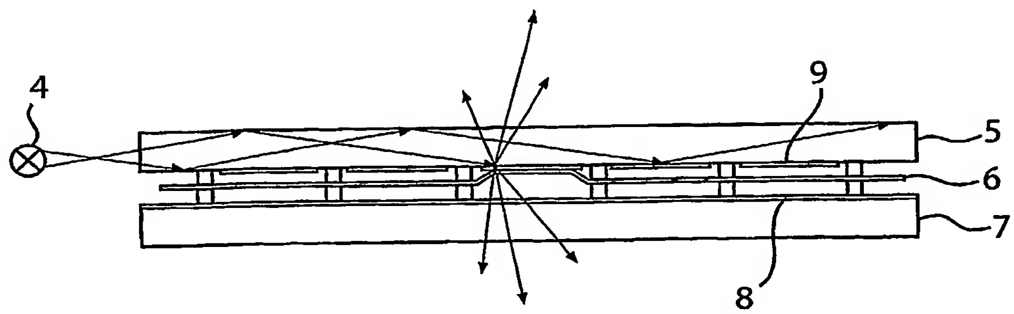
4
9
5
6
7
8

Fig. 4

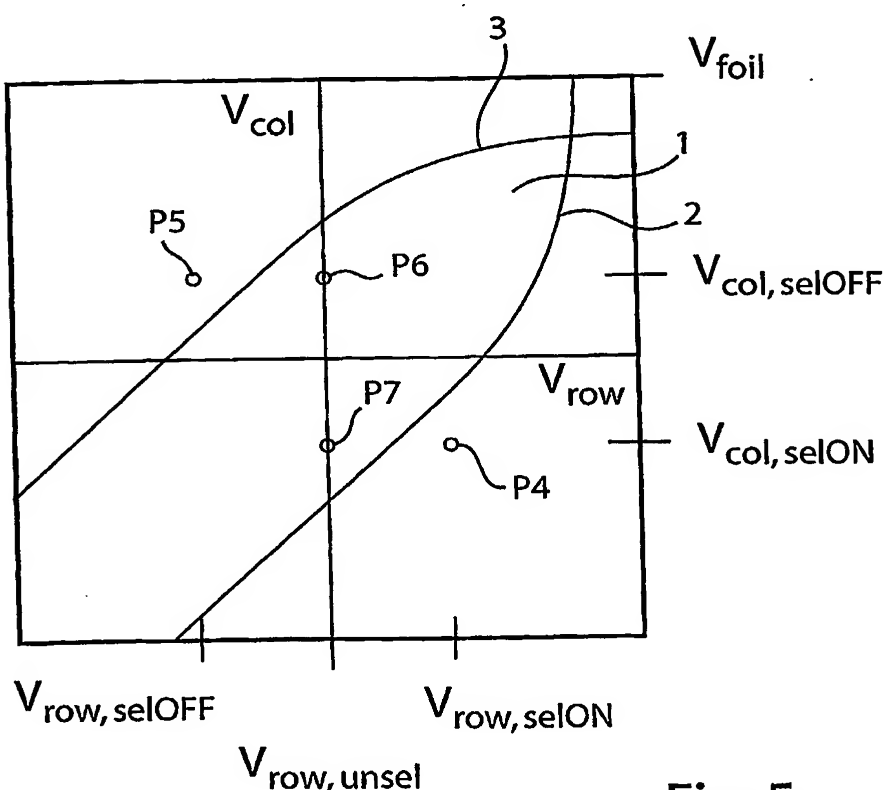
3
$V_{foil}$
$V_{col}$
1
2
P5
P6
$V_{col,selOFF}$
P7
$V_{row}$
$V_{col,selON}$
P4
$V_{row,selOFF}$
$V_{row,selON}$
$V_{row,unsel}$

Fig. 5

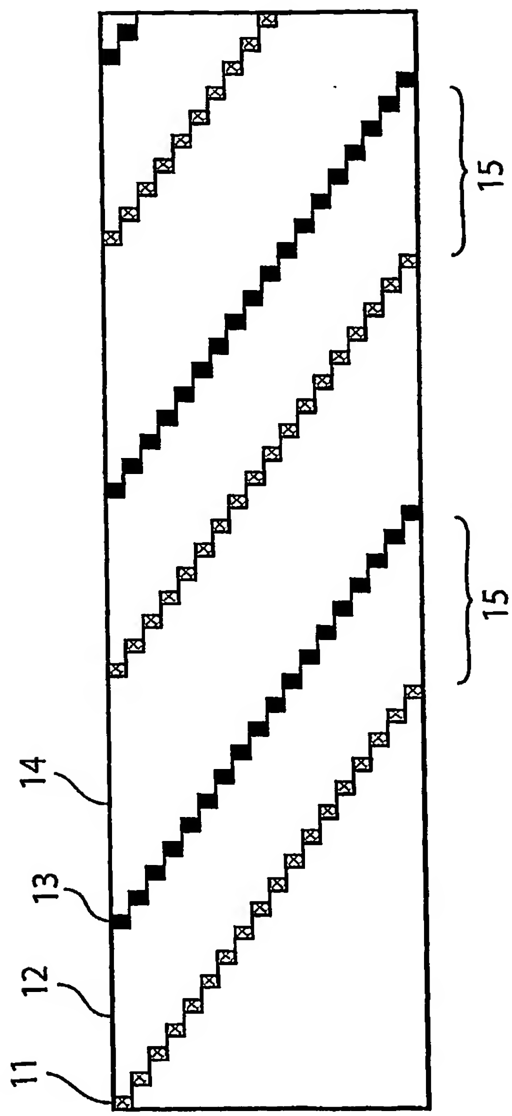


Fig. 9a

PHNL030762



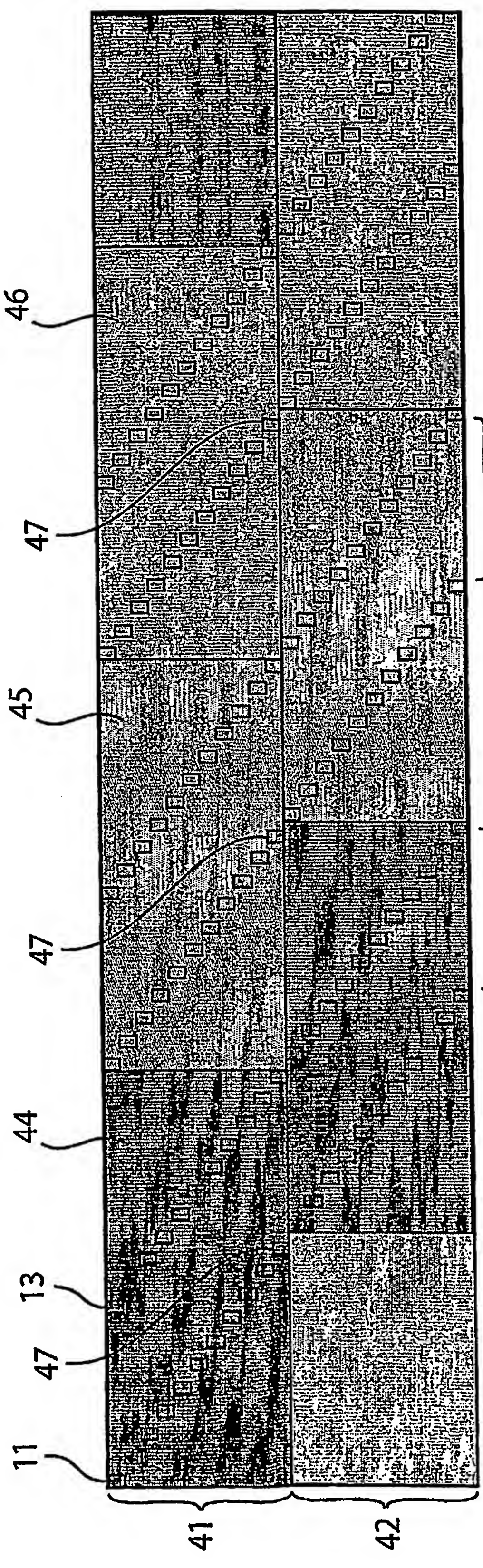


Fig. 9b

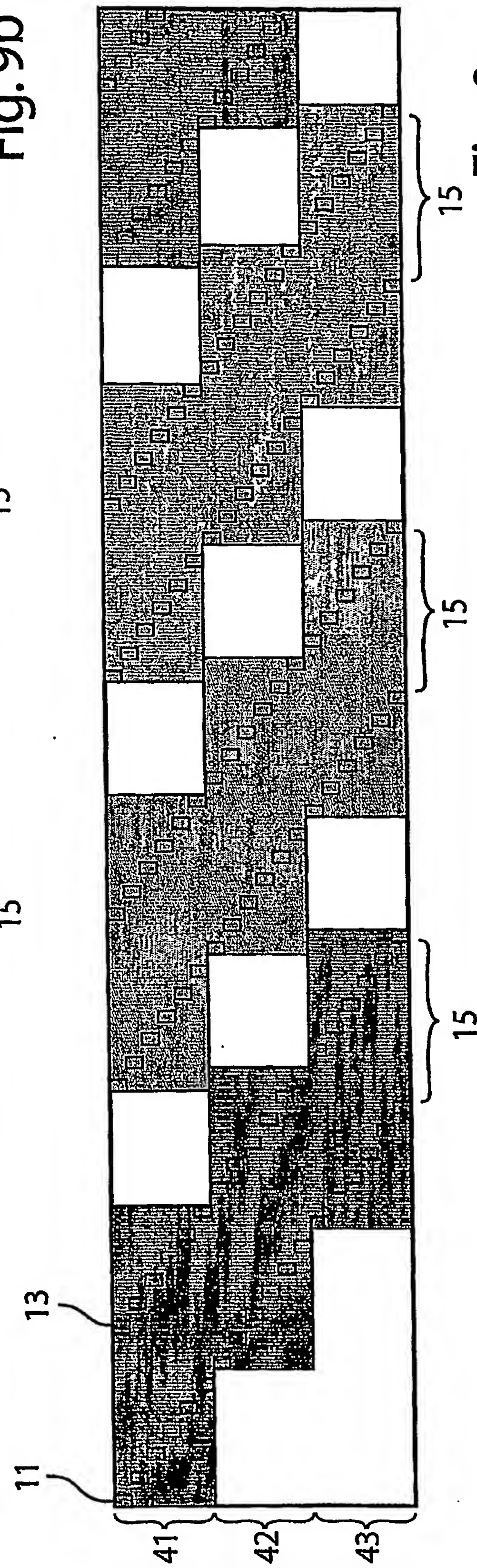


Fig. 9c

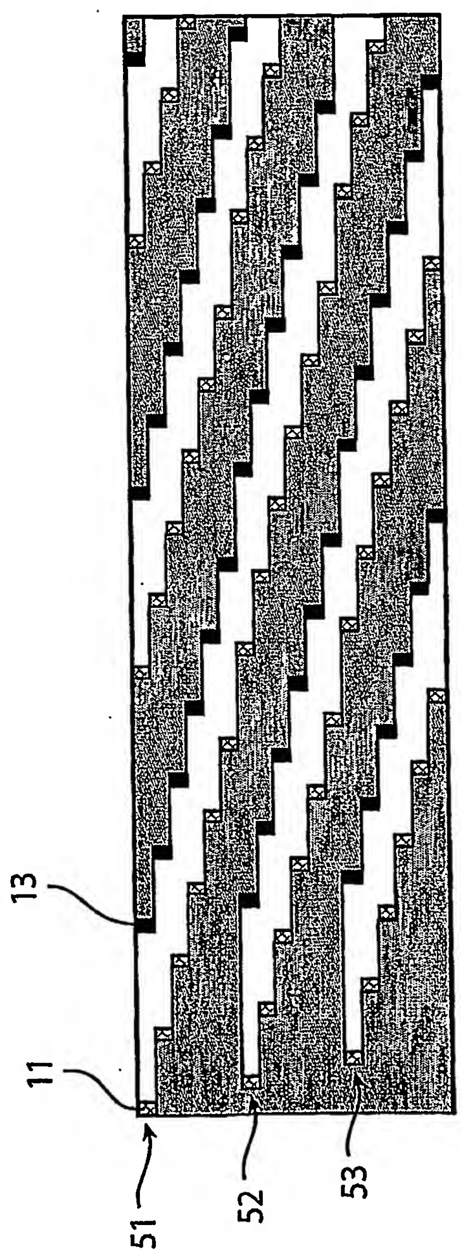


Fig. 10a

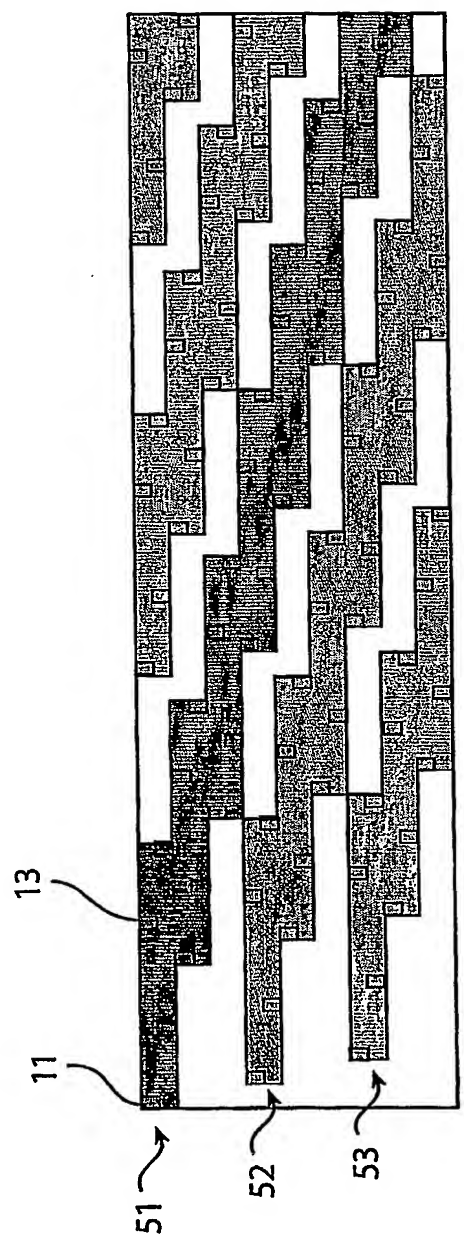


Fig. 10b

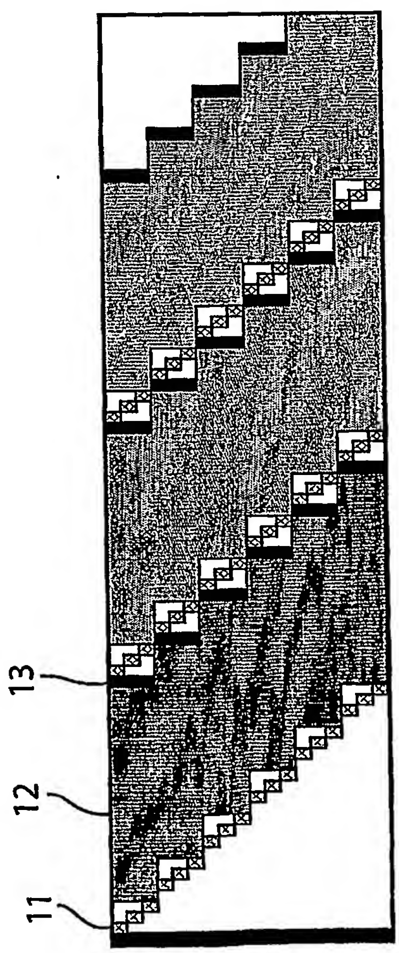


Fig. 11a

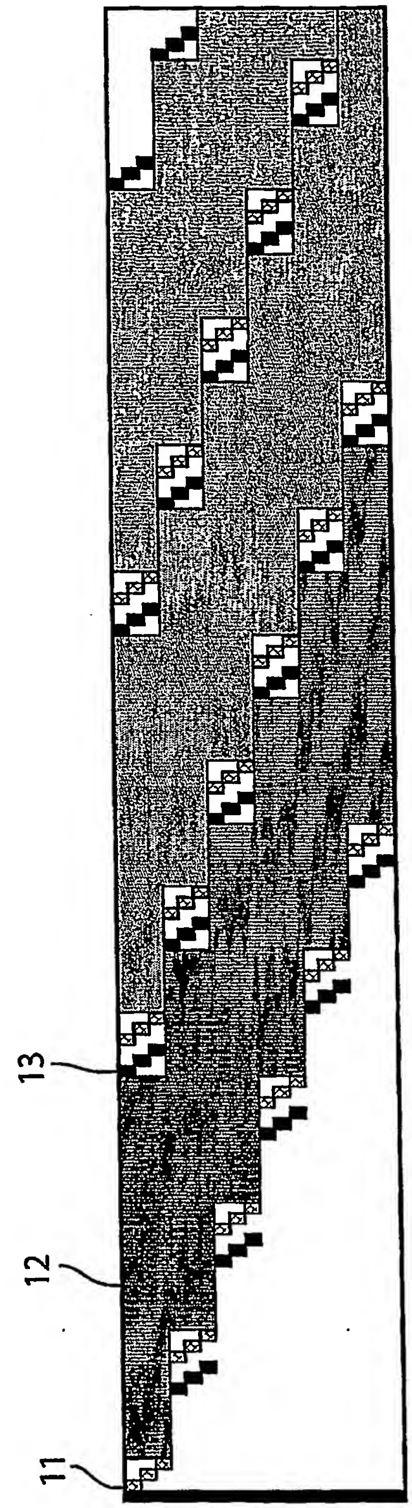


Fig. 11b